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THE PRESERVATION AND STORAGE OF FOODSTUFFS IN THE WEST INDIES.

ONE of the problems created by the war is the threat of the cessation of supplies of foodstuffs from overseas. This has created an increased interest in the preservation and storage of locally produced foodstuffs and has directed attention to the better utilisation of surpluses produced in glut periods. Unfortunately, in the West Indies, transport difficulties preclude the export of perishable crops except under very special conditions, and so there is considerable waste at some periods and shortage, partially relieved by imports, at others. These imports may come from neighbouring islands or from more distant countries. Thus tomatoes are grown successfully in the West Indies at certain seasons of the year, and over very short periods may be produced in such quantities as to be almost unsaleable. But at the same time there is a considerable import of canned tomatoes and tomato products such as juice and sauces. Similarly, quantities of fish may be wasted when catches are heavy owing to the absence of suitable methods for preserving it, while at the same time, large quantities of salt fish are imported.

It is encouraging to know that the problem is being attacked in various directions. One of the difficulties confronting this attack is the lack of information on preservation and storage under tropical conditions, and at present information from America, particularly from the Southern United States, forms the chief basis for further exploratory work. Thus Antigua has a promising fish salting industry, based on Canadian experience. Trinidad is experimenting on the local production of tomato juice and a ladies committee is assisting the Department of Agriculture in an enthusiastic campaign for the home bottling of fruits and vegetables. Here again American experience forms the basis for further trials.

If mixed farming is to be developed in the West Indies, the problem of the preservation of meat and of the utilisation of animal products such as butter will undoubtedly arise. At present, pork is occasionally preserved by curing or smoking, but the products cannot compete with imported ones. Until recently considerable quantities of butter were imported from France; this could

well be replaced by locally produced ghee, although the samples of ghee seen in Trinidad are not all that could be desired.

Apart from the urgent need of supplying local requirements, there is also the hope in happier days of bringing wealth to these islands through the export of preserves such as marmalade, fruit jellies and preserved fruits. Any such scheme would require very careful organisation so that standardised products could be put on the market.

In short, the comparative ease with which food can be obtained all the year round in the West Indies appears to have led to the neglect of the problem of efficient utilisation. No doubt better marketing organisation will help towards this end, but the question of the disposal of surplus products in glut periods will still remain. This problem is now of especial interest, not only because of its immediate practical importance, but also because the better utilisation of local produce would undoubtedly help towards the economic revival of the West Indies. It is to be hoped, therefore, that the various activities already in progress may be supplemented by much wider investigations on preservation and storage under tropical conditions.

THE MAINTENANCE OF SOIL FERTILITY.

The old view that the maintenance of fertility in arable land requires merely the return of the plant foods removed in the crops is now known to be totally inadequate. Among other things it neglects the losses of calcium and nitrate in drainage, and of nitrogen as gas, the conversion of added phosphates and potassium into unavailable forms, and the steady loss of soil organic matter. It fails to direct attention to the deterioration of physical properties under continued cultivation through the destruction of root channels and soil crumbs. Under extreme conditions of torrential rain or prolonged drought, this may lead to soil erosion on a devastating scale. The most effective measure of soil conservation is an active cover of vegetation, the living and decaying roots of which granulate the soil and make it permeable to air and water. Most stable systems of arable cultivation have involved either an alternation with grass, scrub, or forest or the production of large quantities of bulky rotted manure.

The possible chemical, physical and biological effects of farmyard manure are so manifold that their precise analysis has rarely been attempted. The traditional methods often prove unduly expensive under modern conditions and attempts to dispense with them provide severe tests of technical skill. On the other hand uncritical advocacy of old ways may merely retard progress. It is known that lime, the major plant foods, and some of the minor plant foods can be supplied far more economically in inorganic forms, where the principal soil deficiencies are known. Modern methods of soil survey, field experiment and soil analysis can do much to reveal the requirements and potentialities of individual soils, but far more active co-operation between official bodies, farmers and technical workers is needed to develop these methods and extend their use. There is an especial need for field trials over a term of years on the residual effects on soil fertility of different systems of land management.—Dr. E. M. Crowther. *British Association for the Advancement of Science —Report of the Annual Meeting*, 1938, *Cambridge*

CONTROL OF HOUSEFLIES.

A practical method of preventing the development of houseflies in heaps of cattle and horse manure, at small cost in time and materials and without technical knowledge, is described by R. W. Fay (*Journal Econ. Entomology*, 32, p. 851-854, 1940). He regards previously suggested methods as unsatisfactory because of the cost involved or because the manure is rendered less suitable as a fertiliser. In manure heaps at the University of Illinois farm, temperatures of 140° to 170° F. were attained in the interior, but at a depth of four inches they ranged from 112° to 118°. Temperatures of 120° are lethal to housefly maggots, but under moist conditions they can complete their development at 110° to 116°, and average counts of 250 larvae per square foot of the top of two large manure ricks were made.

Control was achieved by piling the manure into ricks with perpendicular sides, and covering them with tar paper (standard 60-pound roofing paper) or, more conveniently, double paper-covered burlap sheets, 20 feet square, impregnated with creosote oil, extending two feet down the sides of the rick. The insulation provided by the cover, and its absorption of heat, raised the temperature of the surface of the manure to 40°F. above that of the surrounding air. All larvae were therefore killed when the air temperature exceeded 80° for a period of five hours. The covers altered the condition of the manure in such a way that, when they were removed after five days, no further eggs were deposited on the heaps and maggots placed in them failed to develop. To trap maggots which were able to migrate from the edge of the covered area and pupate in the ground, a ditch six inches wide and six deep was dug as close as possible to the sides of the rick. Within 12 hours this ditch was filled with liquid seeping from the manure and the larvae were drowned in it. The entire operation of removing and replacing the cover, while adding fresh manure to the heap, occupied only about ten minutes. A. M. A.

ORGANIC MANURING OF TEA.*

Experiments with Cattle Manure, Humus Composts and Unfermented Organic Waste Materials.

Introduction.

THIS memorandum describes large-scale field experiments with various organic and artificial manures applied to mature tea growing in commercial tea gardens in Assam, North-East India. These manurial experiments provide reliable quantitative evidence of the relative value of various composts, cattle manures and waste organic materials, both as regards their effect on yield and in some cases, their cost of preparation. The efficacy of the different manures is also compared, strictly on the basis of nitrogen equivalence, with sulphate of ammonia or other artificial nitrogenous manures. The experiments have been running for three years in most cases, and in some cases even longer; replication and randomisation of the plots are such that statistical methods can be applied for assessing the significance of the numerical results.

The chief advantages recently claimed for composting are (1) that it avoids certain initial harmful effects of unfermented raw organic materials, and (2) that it increases the availability of nutrients contained in these raw materials. The experiments here to be considered give definite information on these points, and thus put to the test certain theoretical arguments which have frequently been raised in discussing the relative merits of artificial *versus* organic manures. It must be stressed, however, that these experiments relate to tea which only grows satisfactorily under conditions of high rainfall in soils having an unusually high degree of acidity. The results obtained do not therefore necessarily apply to other crops grown under other conditions of climate and soil.

Experiments.

In all, nine experiments are separately described. Their main features and results are summarised and brought together in the accompanying table. The soils for the most part are light in texture (coarse and fine sands, sandy-loams and loams), and in two cases, red in colour. Two of the soils are highly humic (*bheel*) soils (Expts. 6 and 7). In all but three cases, the tea was not shaded; it varied in condition, being generally old or very old, up to 70 years. Treatments were replicated from four to seven (in one case ten) times, and yield data refer in all but one case to periods of at least three years' duration. Significant difference values have been worked out for each experiment, and costings are presented for three of the more important trials (*see* Table).

The *artificial manure* employed was usually sulphate of ammonia, since most of the experiments aimed merely at comparing different organic manures on a basis of their total nitrogen contents. In one experiment (No. 9), calcium cyanamide was substituted one year for sulphate of ammonia; in another experiment (No. 7), superphosphate and sulphate of potash were used with and without sulphate of ammonia, and in another (No. 3) "Nicifos" and chloride of potash were used. The effects of phosphate and potash were not considered specifically nor in any detail, however, since nitrogen appeared to be the component mainly responsible for yield increments produced by the different manures in these experiments.

The *organic manures* chiefly comprised composts (used in seven out of the nine experiments), made with such vegetable materials as were available in the vicinity of the tea gardens, mixed with cattle dung, urine-soaked bedding, or "urinated earth". Usually they were periodically wetted from a water supply. In two experiments (Nos. 3, 4), Indore compost, manufactured from rice straw, cattle manure, urinated earth and wood ashes was compared with Dacca compost, made from dried cut jungle bush, and "Nicifos". In each experiment, the same raw materials as used in these composts, but without composting (*i.e.* unfermented), were also compared. In one experiment (No. 4), "Adco" manure, made from rice straw, was tried, and in another (No. 3), a rich animal meal, composed of dried blood, horn, hoof and bone meal, was included. Ordinary cattle manure was employed in three experiments (Nos. 1, 2, 4). In the last experiment (No. 9), a bulky vegetable mulch, consisting of cut bush (*Eupatorium odoratum*), was tested with and without the addition of artificial nitrogenous manure in various proportions.

It is noteworthy that in most of the experiments the aim was deliberately to apply the same total amount of nitrogen in the manures undergoing comparative trial. This is clearly shown in the table. The quantity of nitrogen aimed at was usually 40 or 80 lb. per acre, chemically equivalent to dressings of about 2 or 4 cwt. per acre of sulphate of ammonia.

Results.

The averaged yield data presented in the accompanying table are expressed as maunds of tea per acre (the maund is about 82 lb. weight). The values may differ from those considered for purposes of comparison by the author in the text of his memorandum, since, in order to bring out the full implications of his results, he has usually taken into consideration the yields of the last year or two of the manured plots, by which time increments had reached their maximum. Nevertheless, the results are so outstanding that the

* By H. R. Cooper, *Memo. No.* 11, *Tocklai Experimental Station; Indian Tea Association*, 1940, pp. 36.

MAIN RESULTS AND DATA OF MANURIAL EXPERIMENTS ON TEA.

(After H. R. Cooper, Tocklai Expt. Sta., I.T.A.).

Expt.	Site.	Manurial Treatments.	Size of Dressing. (Lb. ac.)	Total N added. (Lb. ac.)	Total dry org. matter added. (Lb. ac.)	Average Yield. (Maunds ac.)	Increase due to manuring. (%)	Cost of manuring per extra maund of tea made. (Rupees).
1	Halem, Assam.	Artificials	340	41	—	12.94	14.2	9.94
		Cattle manure	16,000	72	2,095	12.45	10.0	7.25
		No manure	—	—	—	11.33	—	—
2	Gandrapara, Dooars.	Sulph. ammonia ...	305	61	—	16.34	18.6	9.00
		Bush ; dung	7,600 2,400	83	5,500	14.67	6.5	16.72
		Compost	11,200	71	1,793	14.55	5.6	17.86
		No manure	—	—	—	13.78	—	—
3	Allynugger, S. Sylhet.	Animal meal	1,450	86	—	7.49	37.9	38.20
		Artificials	492	77	—	7.02	29.3	21.89
		Dacca unferm.	11,650	85	8,330	6.85	26.1	8.19
		Dacca compost	15,660	83	2,740	6.18	13.8	27.84
		Indore compost ...	17,910	85	2,380	5.95	9.6*	40.02
		No manure	—	—	—	5.43	—	—
4	Borbhetta, Jorhat, Assam.	Sulph. ammonia ...	400	80	—	9.12	41.8	—
		Dacca unferm.	—	90	—	8.19	27.4	—
		Cattle manure	—	80	—	7.61	18.3	—
		Indore unferm.	—	80	—	7.50	16.7	—
		Dacca compost	—	70	—	7.48	16.3	—
		Indore compost ...	—	80	—	7.41	15.2	—
		"Adco"	—	80	—	7.30	13.5	—
		No manure	—	—	—	6.43	—	—
5	Leesh R. W. Dooars.	Suplh.amm. 2	400	80	—	14.02	41.1	—
		do. 1	200	40	—	12.53	26.1	—
		Compost 2	22,400	80	—	10.78	8.4*	—
		do. 1	11,200	40	—	10.51	5.7*	—
		No manure	—	—	—	9.93	—	—
		do.	—	—	—	9.63	—	—
6	Aenakhal, Cachar.	Compost	11,200	40	—	7.57	4.1*	—
		Sulph. ammonia ...	200	40	—	7.29	0.3*	—
		No manure	—	—	—	7.27	—	—
7	Luckynugger, Cachar.	S/a ; super	400	40	—	9.72	8.1*	—
		S/a ; s/pot.	280	40	—	9.31	3.6*	—
		S/a ; super ; s/pot. ...	480	40	—	9.20	2.3*	—
		Sulph. ammonia ...	200	40	—	9.17	2.0*	—
		Compost	11,200	40	—	9.16	2.0	—
		No manure	—	—	—	8.99	—	—
8	Champarai, S. Sylhet.	Sulph. ammonia ...	300	60	—	22.94	10.8	—
		Compost	9,000	60	1,440	21.64	3.8*	—
		No manure	—	—	—	20.84	—	—
9	Borbhetta, Jorhat, Assam.	Cyan. 2 ; mulch 2 ...	13,776	165	6,240	9.53	41.8	—
		Cyan. 1 ; mulch 2 ...	13,608	134	6,240	9.02	34.2	—
		Cyan. 1 ; mulch 1 ...	6,888	82	3,120	8.59	27.8	—
		Cyanamide 2	336	60	—	8.00	19.0	—
		Mulch 2	13,440	104	6,240	7.95	18.4	—
		Cyan. 2 ; mulch 1 ...	7,056	112	3,120	8.74	15.2	—
		Mulch 1	6,720	52	3,120	7.21	7.4*	—
		Cyanamide 1	168	30	—	7.21	7.3*	—
		No manure	—	—	—	6.72	—	—

NOTE:—In this table, treatments are arranged in order of magnitude of effect. (F.H.).

* Not Significant.

standardisation of the method of expression as used in the accompanying table does not in any way detract from the conclusiveness of the findings.

In the first three experiments, the costings convey a very good idea of the economics of tea manuring under the conditions that obtain in North-East India, and clearly indicate that, on a strict monetary basis, it may often be advisable to use readily procurable and cheap organic materials rather than the much more expensive imported artificial manures, even though these may prove to be more efficacious in terms of nitrogen contents. The last column of the accompanying table gives the actual cost in rupees (the rupee at par equals eighteen pence) of producing, by manuring, each additional maund of tea over and above that given by the control (no manure) plot.

Summary.

Most of the following statements are abstracted from the memorandum itself. Of the various composts that were tested, "in no case is there "any sign of advantage . . . which could be "ascribed to its content of organic matter or any "auxiliary food factor. On the contrary, the "effect of the artificial (manure) averages about "2½ times that of the compost for the same "quantity of nitrogen, even in the third year "of application or later when residual effects "are operating," although, "in three cases "(Expts. 1, 2, 3), where the work is very well "organised on a very large scale and under "favourable conditions for the collection of raw "material, the work has been done so cheaply "that it represents little if any financial loss". To avoid such loss, "the cost of cattle manure "or compost must be less than one-half of the "cost of the same quantity of nitrogen as "artificial".

In these experiments, "no advantage appears "from the use of cow-dung or urine-earth "as a starter in place of artificial, *i.e.* Dacca "compost proves quite as efficient as Indore "compost." Better results were obtained in three experiments (Nos. 2, 3, 4) with "unfermented "materials (applied) direct to the soil" than with the "same materials after fermentation in heaps or pits". The direct use of unfermented organic materials avoids the expense of manufactured and part of the transport costs, as well as loss of nitrogen by leaching. "For the "same quantity of nitrogen, the unfermented "materials (proved to be) at least as efficient "before fermentation as afterwards". No indication was found that slowly-rotting wood retards the rate at which the nitrogen content of the leafy component of the raw materials is rendered available when applied to the soil.

Conclusions.

As outcome of these findings, the author of this memorandum recommends that the manufacture of composts for the manuring of mature tea in North-East India should be discontinued, on the grounds of its relatively large cost, the liability to loss of nitrogen by leaching, its failure to increase the availability of nitrogen, and the lack of evidence that composts have any value under these circumstances beyond that of the nitrogen they supply. For *young* tea, however, the author believes that composts may be better than unfermented raw materials, though he adduces no evidence in support of this opinion. For old tea, he advocates the greater use of mulches composed of leafy jungle scrub, cut in the vicinity of the tea gardens, dried in the sun, tied in bunches, and carted at cheap rates to the fields. He recommends dressings of three to six tons per acre of such materials. He indicates that bulky organic mulches may protect the land from drought if applied at the onset of dry weather. For manuring mature tea, three tons of dried *Eupatorium* cuttings proved to possess the same value as 150 lb. of ammonium sulphate, costing Rs.14-0-0, (about 21 shillings) at war prices, (including freight), which implies that the monetary value of the dried cuttings would be about Rs.4-0-0 per ton (about six shillings), corresponding to Rs.2-12-0 (four shillings and three half-pence) per ton of freshly cut undried material. It is considered that, wherever suitable material is available conveniently near to tea gardens, it should be possible to cut and cart it at costs below these figures, at least for part of the area of each garden.

F. H.

ROOTING OF SOFTWOOD CUTTINGS OF *COFFEA ARABICA*.

The method of rooting coffee from softwood cuttings at the Coffee Research Station, Lyamungu, Tanganyika, is described by L. M. Fernie in the *E. Afr. Agr. J.*, 1940, 5: 323-9. To establish a clonal race, about 20 rooted cuttings of the selected tree are planted out in nursery rows 4 to 5 feet apart and allowed to grow up on multiple stem. In from 18 months to two years the remaining primary branches are removed and each stem pegged down horizontally. Suckers then grow up vertically from the dormant eyes at the node and can be taken as cuttings. A minimum of three new suckers should be left near the base for pegging down for succession. The top of each stem is left to draw the sap the full length of the plant and this can be pegged down as growth proceeds. The cuttings are struck in closed glass frames maintaining a high humidity; the medium is peat moss 2 parts and sand 1 part.*

* For a full account of past and present methods used in the vegetative propagation of coffee, see "Vegetative propagation of tropical and subtropical plantation crops". *Tech. Comm.* 13, *Imp. Bur. of Hort. & Plant. Crops, East Malling*, 1940, 3*s.* 6*d.*

The Editor requests that any subscriber who fails to receive *Tropical Agriculture* regularly should communicate with him immediately in order that the matter may be rectified.

CINCHONA IN GUATEMALA.

By Wilson Popenoe.
(*United Fruit Company*).

The comprehensive summary of recent progress in Cinchona cultivation throughout the world published in the Bulletin of the Imperial Institute, 1939, includes only brief mention of the work which has been done in the Republic of Guatemala. Since those experiments show considerable promise, it is hoped a general survey of results obtained to date may prove of interest.

Botany.

To render intelligible this discussion it is necessary to consider briefly the botanical status of the plants grown as sources of the drug quinine. Weddell, who devoted exhaustive study to the genus Cinchona in the early days, published in 1848 a list comprising 21 species. Later, in 1870, he revised his classification, extending it to include some 37 species and 15 subspecies. Many of these, in the light of later study, seem more properly to be considered as geographical forms or varieties. The summary made by the Imperial Institute, mentioned above, states:

"Four species only have been cultivated to any extent as a source of alkaloids. These are: *C. ledgeriana* Moens ex Trimen (known also as *C. calisaya* Wedd. var. *ledgeriana* Howard), from which Ledger bark is obtained; *C. succirubra* Pavon ex Klotsch, the source of Red Bark; and finally *C. calisaya* Wedd. and *C. officinalis* Linn., yielding Yellow Bark and Crown Bark or Loxa respectively. Two hybrids may also be mentioned, namely, *ledgeriana*×*succirubra*, known as Ledger hybrid or sometimes as *C. hybrida*, and *officinalis*×*succirubra*, which is usually called *C. robusta*. At the present time practically the entire supply of cinchona bark in commerce is obtained from *C. ledgeriana* and *C. succirubra*."

This classification, though greatly reducing the confusion in which the subject was left by the early botanists, is considered by certain American students as requiring still further simplification. Paul C. Standley, who has devoted much study to the Rubiaceae of tropical America, reduces the species involved in commercial quinine production to *C. officinalis* Linn. and *C. pubescens* Vahl (*C. succirubra* Pavon), justifying his stand in the following words (cf. *The Rubiaceae of Ecuador*, Field Museum of Natural History, Publication No. 285, Chicago, 1931):

"Because of the great economic importance of the trees concerned and especially because of the varying quinine content in the inhabitants of the various regions, several botanists have devoted a great deal of time and hundreds of printed pages and plates to a discussion of the species of the genus. The result of their work has been the description of a great number of so-called species, based on characters that certainly would not be considered valid or important in other genera of the Rubiaceae. The writer has examined a large amount of herbarium material of the genus, as well as photographs of many of the types involved. He is quite unable to discover any conservative basis for recognizing the many species to which names have been given, and he believes that these names relate to variable races of a few not very clearly marked species which may be recognized for botanical convenience. The mere fact that the variations of these races are important from the standpoint of the pharmacist does not justify their recognition, if such were possible, as species in the ordinary sense of that term."

Admittedly the last word has not been said regarding the botanical status of those forms of Cinchona which yield quinine commercially. Admittedly further study may alter the classification adopted by Standley. But the simplification of the agricultural problem by the elimination of numerous questionable species, which do not invariably come true when grown from seed, seems so logical and so practical that Standley's classification has been accepted by those working with Cinchona in Guatemala at the present time. *C. ledgeriana* is therefore not recognised as a species; neither is *C. calisaya*. Both are forms of *C. officinalis*, a widely variable species which hybridizes freely with the other one which produces commercial quinine—*C. pubescens* (more commonly known as *C. succirubra*), giving rise to forms which often go under the name of *C. robusta* but which more properly are to be termed *officinalis*×*pubescens* hybrids.

Agriculturally, it is becoming the practice in Guatemala to refer to trees of the species *officinalis* as calisayas; those of the form known elsewhere as *C. ledgeriana* as Ledgers or calisayas of the Ledger race; trees of the species *pubescens* as succirubras; and all hybrids between *officinalis* and *pubescens* as hybrids rather than *C. robusta*. Without presuming to say that this terminology will stand the test of future botanical investigation, it is felt that its simplicity recommends it.

Historical.

The stimulation of interest in Cinchona culture shortly after the middle of the last century, resulting from the successful efforts of the British and the Dutch to transplant Cinchona trees from their native home in the Andes to plantations in the Eastern tropics, had repercussions in several regions, of which Guatemala seems to have been

one. For we can only attribute to this cause the introduction of Cinchona into this country about the year 1870, a work which seems to have been fostered by that remarkable man, President Justo Rufino Barrios. Details are difficult to obtain at this late day, but it is known that Barrios planted cinchona extensively on his property "El Porvenir", in the Department of San Marcos, where the progeny of his original trees still grow in vast numbers. An examination of these half-wild trees today suggests that Barrios brought in both *C. officinalis* and *C. pubescens*. As would be expected, the latter is the one which has survived, most of the present trees being unquestionably of that species; but there are sufficient indications of calisaya blood to convince one that hybridization has taken place, and that while the more delicate *officinalis* has disappeared, its memory still lingers in the narrow, smooth leaves, the white flowers, and the relatively high quinine content of numerous trees scattered over the slopes of the volcano Tajumulco which dominates this beautiful property.

Shortly after the death of Barrios the Reformer a serious effort was made by Germans to establish Cinchona cultivation in the Department of Alta Verapaz, of which we fortunately have an account in the memoirs of Franz Sarg, published in "Deutschtum in der Alta Verapaz", 1938. Sarg states that the Minister of Agriculture, Don Manuel Herrera, offered a prize of fifteen hundred pesos to the man who would make the first planting of two thousand trees. Through the good offices of Prince Nikolaus of Nasuas seeds were obtained from Ceylon in 1878, and in 1882 the prize was claimed and paid. Difficulty in handling the bark, and falling prices in the world market, discouraged the undertaking and the project was dropped. But two old trees at the Finca Sachamach, near Cobàn, still remain to testify that here again the effort was not limited to the introduction of the relatively inferior succirubras, but that calisayas also were involved; for these two trees, which may be seedlings of some of the first ones planted, show definite evidence of calisaya blood—again in their leaves, their flowers, and their relatively high quinine content.

After these early efforts, from which no pecuniary profit seems ever to have been derived, interest lapsed for half a century. Then, with a view to developing a Cinchona industry capable of supplying the North American market with quinine, experiments were started which had the support of the Guatemalan and the United States governments. Seeds of the Ledger race were obtained, and later, through the good offices of the Division of Plant Exploration and Introduction of the United States Department of Agriculture, other promising strains were brought into the country. Nurseries were established in several places; Don Mariano Pacheco, Director General of Agriculture for the Republic of Guatemala, gave the subject his personal attention; and work was under way which in the past two years has commenced to show promising results.

Commercial Cinchonas and their Characteristics. Naturally, these recent experiments in Guatemala have had as background the available literature upon the general subject of Cinchona cultivation in other regions, particularly Java, which at present supplies 95 per cent. of the world's quinine. The literature, while by no means extensive, is sufficient to point out the objectives which must be attained if success is to be achieved. Of particular value has been W. N. Sands' account of the Cinchona Industry in Java, published in the Malayan Agricultural Journal, 1922; and "De Kinacultuur", by A. Groothoff, published at Haarlem, Holland, in 1925. A more recent work of value, from a different region, is E. H. J. Stoffels' bulletin "Le Quinquina", published by L'Institut National pour l'Étude Agronomique, Belgian Congo, 1939.

These publications by no means exhaust the list, of course, and it is perhaps well to mention once again the excellent summary compiled by the Imperial Institute, referred to at the beginning of this paper. From this last-named publication, and bearing in mind the fact that the Ledger race of calisaya is today the source of most of the quinine produced commercially, the following quotation is of more than passing interest:

"It has already been mentioned that *C. ledgeriana* is more exacting in its requirements than any other species. The most suitable climatic conditions for satisfactory bark production of high quinine content would appear to be those obtaining in Java at elevations of 4,000 to 5,000 feet. The character of the soil is also of great importance in the case of this species; its first essentials are that it should be friable and of good depth, the best results in Java having been obtained on such soils recently cleared of forest. Other species, especially *C. succirubra*, on the other hand, will thrive and give relatively good yields of alkaloids under conditions where *C. ledgeriana* would fail. For this reason, and owing to the uncertainty of successfully re-establishing *ledgeriana* on old cinchona lands attention has been paid to the question of grafting the latter species on the more vigorous *succirubra* stock. This has proved highly successful and practically all the Ledger bark now being produced in Java is harvested from grafted trees."

Work in Guatemala commenced with full appreciation of the fact that experimentation is required to determine which kinds are best suited to profitable commercial exploitation under the particular conditions of soil and climate existing in this country; but also, with understanding that high-yielding Ledgers such as

those grown in Java have fully demonstrated their value and might here prove to be the best. More time will be required to determine for any given area just what is right. The situation, so far as can be judged at long range (since Java is accepted as the guide), sums itself up about as follows:—

Ledger seedlings on their own roots.—These are held to be the ideal thing, where conditions for their development are satisfactory. They have the advantage that root-bark as well as stem-bark contains relatively high percentages of quinine, whereas Ledgers grafted on succirubra rootstocks suffer from the disadvantage of the relatively low quinine content of the root-bark. There is the further advantage that the expense of grafting is avoided.

Ledger clones on succirubra roots.—These can be grown on soils not sufficiently rich for Ledgers on their own roots. Vegetative propagation provides foreknowledge regarding quinine content of the ultimate tree, a distinct gain since it is a notorious fact that Cinchona seedlings are in nearly all instances subject to much variation.

Calisayas other than those of the Ledger race.—These were given a trial in the Asiatic tropics before the advent of Ledgers (the history of which is too well known to require mention here), and the fact that Ledgers have completely superseded them speaks volumes. Nevertheless, the literature makes little mention of new trials in the past half century, and there seems a definite possibility that the Andean region, native home of the Cinchonas, may still yield forms of *C. officinalis* which, under certain conditions of climate and soil, will have commercial value.

Succirubras on their own roots.—These are of more rapid growth than Ledgers, and can be cultivated successfully on many soils not suited to the latter; but their quinine content is low and they are not considered commercially very satisfactory—except where there is an interest in alkaloids other than quinine, such as cinchonidine and quinidine, of which succirubras sometimes contain relatively large percentages.

Hybrids, C. officinalis × *C. pubescens.*—These are frequently mentioned in the literature and there can be no doubt that some of them have played a part in commercial production. Many have the advantage of being more robust than Ledgers, and of more rapid growth. As a rule, their quinine content is lower than that of good Ledgers; but the volume of bark produced at a given age may be considerably greater, hence the lower quinine content is in part offset. There is the added circumstance that hybrids often grow well on soils which will not support Ledger seedlings. Due to their mixed genetic constitution, however, it seems probable that it will be necessary to graft hybrids onto succirubra stocks if uniformly good results are desired.

Results of Experimentation to Date.

The pioneering done in the 1870's and 1880's has left large numbers of Cinchonas—mostly succirubras, with a few evidences of calisaya blood at Coban and El Porvenir—scattered over Guatemala, chiefly in the Alta Verapaz and on the coffee plantations of the Pacific side. But the information gained in the early days regarding the adaptability of Guatemalan soils and climates to the culture of calisayas is lost. Present efforts to determine the commercial possibilities of Cinchona culture in this republic have had to be based on the fact that nothing is known and everything is to be learned.

Seeds of high-grade Ledgers were obtained and nurseries formed at several places which in the light of information gleaned from the literature seemed promising. Lack of experience naturally resulted in the loss of many seedlings; but sufficient were saved to plant several small experimental areas, chiefly at Finca Helvetia (Department of Retalhuleu), Finca Samac (Alta Verapaz), Finca El Zapote (Escuintla) and Finca Panamá (Sololá). These plantings ranged in elevation from 3,500 to 4,500 feet, and represented a very considerable range of climatic conditions.

Many of these trees have attained sufficient size to show interesting responses to environmental conditions, and to permit of bark analysis. Best growth has been obtained on the brown, deep, volcanic fine sandy loams and silt loams of the Pacific side, and on the alluvial clay loams of the Coban region. On the black sandy loams— one of the chief soil types of the Pacific side—results have not been so good; though it may be noted that in all cases these Ledger seedlings have been planted on land which for many years previously had grown coffee or other crops.

Since writers on Cinchona cultivation in Java repeatedly stress the necessity of using virgin lands for Ledger seedlings, it cannot fairly be said that experience in Guatemala on old lands of the black sandy type is discouraging.

In considering the results of bark analyses it must be remembered that samples are taken from precisely that part of the tree which contains the highest percentage of quinine, namely, the trunk at about three feet from the ground. Bark from the smaller branches does not show such high percentages, nor does that from the roots. On the basis of the available literature, Ledger seedlings which show 12 to 13 per cent. of quinine sulphate when bark-sampled at the age of five to six years can be considered good; and such trees are now growing in Guatemala.

From these trees it should be feasible not only to develop satisfactory sources of high-grade seed for further planting, but also, and perhaps even more important, select the most vigorous and disease-resistant individuals, and those with the thickest bark, for the establishment of clones to be propagated by grafting on succirubras.

Not a few such clones have already been chosen and are being propagated as rapidly as possible. W. N. Sands (*loc. cit.*) has enumerated the principal factors which should be taken into account when selecting individuals for vegetative propagation, and his description of the Java technique has been accepted as the best guide until such time as adequate experience has been gained locally.

In addition to trees of Ledger race now established in Guatemala there are numerous others obtained from several sources through the co-operation of the United States Department of Agriculture. And there are many seedlings from the old trees at Sachamach near Coban, broad-leaved forms of apparently mixed blood, vigorous in growth and suitable for cultivation on lands not rich enough for Ledger seedlings. Some of these, and some of the broad-leaved trees presumably of hybrid origin which have been introduced from other regions, have shown quinine contents of 6 to 7 per cent., which is considered satisfactory in view of their rapid growth and thick bark.

Unfortunately, the altitudinal range of the first experimental plantings does not include elevations above 4,500 feet. Recently, therefore small plantings have been made at higher levels—up to 6,200 feet in one instance—to test the possibilities of the zone immediately above that in which coffee is profitably grown in this republic. For it will greatly facilitate the development of a Cinchona industry if coffee planters can use for this crop lands between 5,000 and 6,000 feet in elevation. Many planters possess such lands which because they were not considered suitable for coffee are still in virgin forest.

Propagation.

The production of succirubra seedlings on which to graft Ledgers offers few difficulties. Successful production of Ledger and other calisaya seedlings, on the other hand, requires good technique and attention to details; while grafting is in this case, as with many other trees, something which can be successfully carried out only when it is backed by a certain amount of experience and knowledge of essential factors.

To the experienced horticulturist, in other words, there is nothing in the propagation of Cinchona, asexually or sexually, which presents serious problems; but the tropical agriculturist accustomed only to the simpler techniques of cane, coffee or banana culture (for example) will find the propagation of Cinchona difficult until he has devoted much time to a conscientious study of details.

Seed beds.—The basic principles underlying the propagation of Cinchona from seed appear to be these: the seeds must be kept uniformly moist while they are germinating, and should be given very little light. If allowed to dry out once they have commenced to swell, they die. Immediately they have germinated, they are endangered by the risk of "damping off" against which they must be protected by a delicate adjustment of light and ventilation, assisted in some instances by a judicious use of Bordeaux mixture. In a few weeks' time they are out of danger, so far as damping off is concerned, and must be given more light, gradually, without exposing them to the direct rays of the sun.

The type of seed bed used in Guatemala differs in no major respect from that described in the literature; indeed it has been patterned after the latter. Obviously, local experience is still meagre in this as in many other respects. Protection from the sun is usually provided by sheet-iron ("lamina") roofing which is easily obtainable in most parts of tropical America and which can be used repeatedly for many years. Seed beds should not be wider than three or four feet: the length is optional. The roof should have a steep slope, from north (the higher side) to south. It is important that good ventilation be provided on both sides, and the bed should run from east to west so that light can be admitted, in gradually increasing intensity, on the northern side without letting the sun have direct access to the plants. During the first few weeks (germination usually takes place in 20 to 30 days) the beds are kept dark by using bamboo mats, canes, or other convenient material along the northern side. Adjustment from time to time permits the necessary increase of light as the plants develop and require it.

The beds are surfaced with an inch or two of rich forest loam or leaf-mould. The seeds are sown at the rate of two to three grams per square yard of surface (a gram contains 2,000 to 3,000 Ledger seeds): if sown more thickly, it has been found that the danger of damping off is greatly increased. Though it is not necessary to cover the seeds with soil, it is local experience that drawing a very fine-toothed rake gently over the surface after sowing, aids in securing a good germination.

Nurseries.—The time which must elapse before seedlings are ready to be transferred from seed beds to nurseries varies greatly with the climate—in other words, the altitude above sea level. In general it ranges between six and ten months. Before they are moved, the seedlings—which should be about two inches high—are hardened gradually by exposure to more light. If not sufficiently hardened, moving is fraught with considerable risk of loss. If hardening is attempted too suddenly—that is, if the plants are exposed to the full force of the sun's rays—the risk is just as great.

Nursery beds are carefully prepared and provided with shade of some sort to reduce the amount of light which reaches the young plants at the start. Here again experience and assiduous attention to details are essential. Plants are spaced 2 × 2 inches to 6 × 6 inches apart, the spacing depending upon the size they have

reached at the time they are moved, and the programme to be followed later: if spaced closely a second transplanting is necessary, since 6 × 6 inch spacing is required during the few months before the trees are ready to be transferred to permanent locations in the field.

Fortunately, Cinchona seedlings, if properly grown and "hardened off", transplant very readily, even when moved, with bare roots.

Grafting.—The technique at present employed in Guatemala is that which has been developed by Jorge M. Benitez, Plant Propagator of Experimental Plantations Inc. at Finca El Naranjo, Chicacao—principal base of experimental Cinchona cultivation in this republic.

It differs slightly from standard practice in Java if one can judge by published descriptions of the latter.

The essentials of grafting seem to be these: stock plants (invariably of the species *pubescens* or *succirubra*) must be strong and vigorous, with stems one-half to three-quarters of an inch in diameter at the ground. Scions must be of sound, half-ripened wood. And the work should be done in damp weather if best results are expected.

In other words, the principles are the same as with other trees, and are familiar to horticulturists. The percentage of success varies, however, with different varieties, the strong-growing hybrids such as those known in several countries as "robustas" being much easier to graft than the more delicate Ledgers.

Young trees in vigorous growth provide better scions than older trees. Blossoming wood should not, of course, be used. The scions should be about four inches in length, and of the thickness of a lead pencil. They do not need to be terminals, but should have two nodes toward the upper end. The leaves are carefully trimmed off with the grafting knife and a diagonal cut about two inches in length is made toward the lower end. This cut is placed against a long shallow cut on the side of the stock-plant, so that the cambium layer of the scion comes into direct contact with that of the stock. Holding the scion firmly in place with one hand, the graft is then bound with waxed tape, made by boiling cheap muslin in a mixture of beeswax and resin. After this is done, the graft is covered completely with warm melted wax applied with a one-inch brush.

Union takes place in four to six weeks. After the scion has commenced to grow vigorously, the stock-plant is cut back gradually. In about one year's time the grafted plant is ready for moving into its permanent location in the field.

The best months for grafting in Guatemala are considered by Benitez to be June and July, though the work can be done very satisfactorily at any time between the onset of the summer rains in May and the season of heavy rains in September-October.

Field Culture.

Obviously, Guatemala lacks extensive experience regarding this subject. Plantings now being made are spaced variously, from a minimum of 4 × 4 feet to a maximum of 10 × 10 feet. Practice in Java—again as described by Sands and others—suggests close planting and later thinning out for the exploitation of the bark. The culture given in the field is much the same as that used for coffee — another rubiaceous plant — primarily because this technique is familiar to Guatemalan agriculturists.

Little is known, as yet, regarding pests and diseases which must eventually be faced by the Cinchona planter in this country. It seems usually to be the case that enemies develop more abundantly when their host plants are cultivated on an extensive commercial scale.

COFFEE GROWING IN JAMAICA, COSTA RICA AND COLOMBIA.

In a report (14 pp.) S. Gillett of *Scott Agric. Labs. Dep. Agric., Kenya*, makes a general survey of the coffee industries of Jamaica, Costa Rica and Colombia. The field and factory conditions for the benefit of the coffee growers of Kenya are described. On the scientific side information was acquired, particularly on the subject of quality, which is to lead to experimentation on new lines, but these matters are not discussed. Most attention is paid to Costa Rica. In all three countries much damage has been caused by erosion. The consistency of the Costa Rica growers in adhering formerly to a system of growing which has proved its value is pointed out as an example to be emulated in young countries where frequent changes of system, especially in pruning, are in vogue. A system of establishing multiple-head plants in the supply nursery before planting out is worthy of consideration as being easier and cheaper than forming such plants when scattered in the field. The young plants spaced wider than usual in nursery beds are bent over when 15 months old. Later four heads are selected and the original bent over stem cut off. Nine months later these established multiple-headed plants can be planted out. The question of supplies is considered very important in Costa Rica and the use of a ball of earth or basket planting when planting out supplies is considered essential. The dying out of the shade tree (*Inga* sp.), commonly used in both Costa Rica and Colombia, shows the importance of using mixed plantings of shade trees instead of relying on one variety only. The extreme care taken by the Costa Ricans in the factory preparation of the bean for the London market, especially in grading, curing and hand picking, results in the production of a high quality coffee and is an example that might well be followed elsewhere. — (From *Horticultural Abstracts.* Vol. X, No. 3. pp. 287-8.)

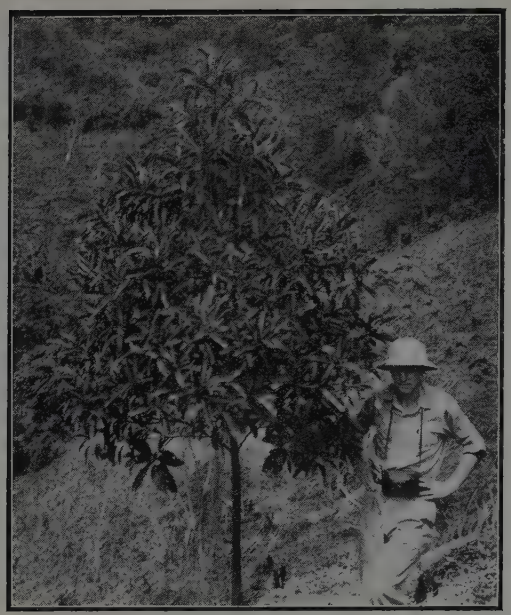

FIG. 1.—Seedling tree of good Ledger character, four years in the field. Finca Helvetia, Depto. de Retalhuleu, Guatemala.

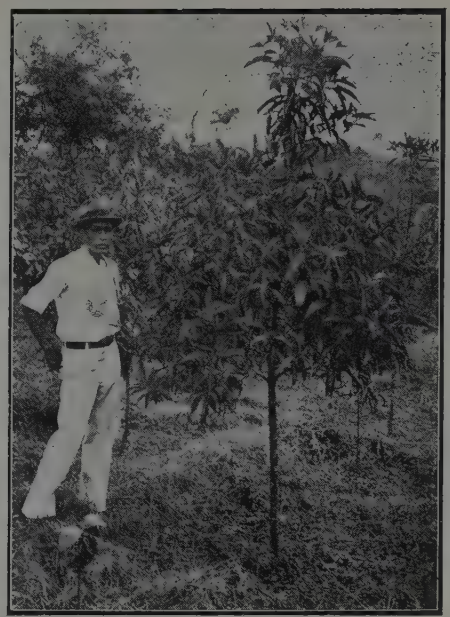

FIG. 2.—Grafted tree of good Ledger character, three years from planting in the field. Finca El Zapote, Depto. de Escuintla, Guatemala.

FIG. 3.—Ledger tree in seed, showing also the character of the foliage. Finca Helvetia, Depto. de Retalhuleu, Guatemala.

FIG. 4.—Seed beds at Finca El Naranjo, Chicacao, Guatemala. Recent experience indicates that the roofing which is of sheet iron, should have a steeper pitch than that shown here.

FIG. 5.—Close view of seed beds, Finca El Naranjo, Chicacao, Guatemala. Light from the sides is controlled by adjusting the position of the thin canes here visible.

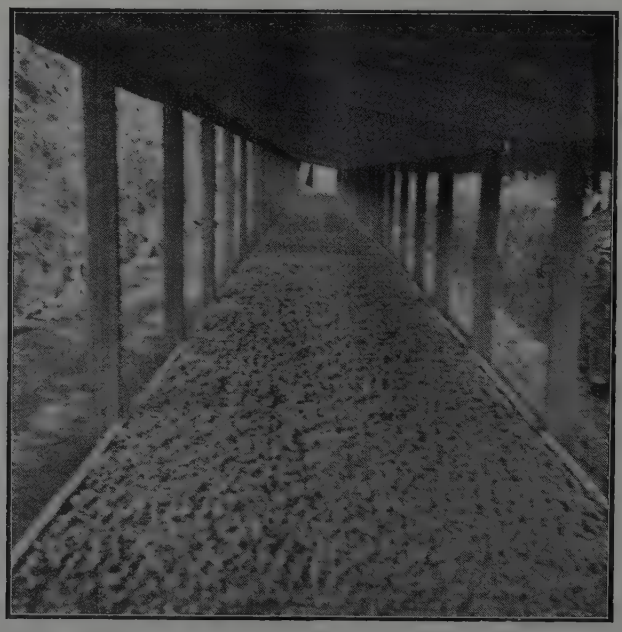

FIG. 6.—Calisaya seedlings six months old in seed beds at Finca El Naranjo, Chicacao, Guatemala.

FIG. 7.—Recently-grafted succirubra seedlings in nursery at Finca Panamá, Depto. de Sclolá, Guatemala.

FIG. 8.—Root system of well-grown succirubra seedling suitable for grafting. Finca El Naranjo, Chicacao, Guatemala.

FIG. 9.—Young Ledger branchlets suitable for furnishing scions to be grafted on succirubra seedlings. Finca El Naranjo, Chicacao, Guatemala.

FIG. 10.—Ledger scion in place on a succirubra stock, ready for tying and waxing. The stock-plant has been removed from the soil to facilitate photographing. Finca El Naranjo, Chicacao, Guatemala.

THE TEACHINGS OF THE DOMINICA CACAO-MULCHING EXPERIMENT.

By F. Hardy.
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(1) Introduction.

In his memorandum appended to the Final Report of the Committee appointed to enquire into the needs of the cacao industry of Trinidad*, Sir Frank Stockdale refers to the manurial experiments in Dominica as having "shown the value of mulching in the improvement of crop yields of cacao". Although this experiment is no longer in being (it ran from 1900 to 1930), the yield data and observations, fully recorded in Annual Reports of the Agricultural Department of Dominica, are worthy of consideration in a further attempt to assess the relative value of vegetable mulches and of combinations of artificial manures in the production of cacao.

The experiment in question was laid down by Dr. (later Sir) Francis Watts and Mr. Joseph Jones at the Roseau Botanic Station on an area of flat land bordering Morne Bruce.

(2) History of the Dominica Experiment.

The course of the experiment comprises three distinct periods, namely, (I) 1900 to August 1913, (II) August 1913 to July 1922, (III) July 1922 to September 1930.

The *First Period* was one of development, with little or no interference by adverse weather. At the end of this period, a thorough investigation of soil and crop conditions in the various plots was undertaken by Dr. H. A. Tempany, then Superintendent of Agriculture for the Leeward Islands. The results of this investigation were published in full†; it is with this phase of the experiment that the present article is mainly concerned.

The *Second Period* was one of adverse weather. High winds in August 1913, and hurricanes accompanied by exceptionally heavy rains in August and September 1915, and again in September 1916, severely damaged both trees and soil of the plots. Several trees were uprooted and many were badly shaken. A rapid downward trend in cacao yields ensued from peak production in 1915 to record low production in 1922. The last four years of the period were unusually dry; only 67 inches falling on the average in each year, as compared with the previous 25 years' average of over 78 inches.

The *Third Period* was one of even more disastrous weather. Storms occurred in September and October 1924, and hurricanes of great intensity in July 1926, September 1928, and September 1930. The first two years (1922-24) were exceptionally dry; with only 55½ inches of rain, though the subsequent years were somewhat wetter than normal, with a mean annual rainfall of about 80 inches. The September 1928 hurricane completely destroyed two of the trees and "so badly damaged 39 others that it was doubtful if they would ever recover". The intensity of the last hurricane (of September 1st, 1930) is described as "unparalleled within living memory of the Island's inhabitants". Nearly all the cacao trees were blown over, and 236 trees were uprooted. The experiment was consequently abandoned.

* Council Paper No. 61 of 1940, Trinidad and Tobago, p. 27.

† A Study of the Results of the Manurial Experiments with Cacao conducted at the Botanic Station, Dominica. H. A. Tempany. *West Ind. Bul.*, XVI, 1915, pp. 81-119.

(3) The First Period of the Experiment (1900-1913).

The land originally carried 10-year old cacao trees of Forastero-Calabacillo variety, planted about 16 × 16 feet apart without shade.* The area was divided into five plots to which different manurial treatments were given from the start. The following manures were applied annually, being merely spread on the ground and not forked in.

Plot A.—(37 trees, 0.29 ac.) Basic slag, 4 cwt. ac.; sulphate of potash, 1½ cwt. ac.

Plot B.—(40 trees, 0.36 ac.) Dried blood, 4 cwt. ac.

Plot C.—(34 trees, 0.28 ac.) Control; no manure.

Plot D.—(39 trees, 0.37 ac.) Vegetable mulch, 5 tons ac.

Plot E.—(34 trees, 0.29 ac.) Dried blood, 4 cwt. ac.; basic slag, 4 cwt. ac.; sulphate of potash, 1½ cwt. ac.

The vegetable mulch consisted of leaves and pods of the Saman tree (*Pithecolobium Saman*) and cuttings of Savanna Grass (*Axonopus compressus*), gathered from the lawns of the Botanic Gardens. Yields were recorded from the beginning of July to the end of June each year; they are tabulated in the Annual Reports of the Station from the year ending June 30th, 1903. Because of the irregular stand of trees, it was

* There is some confusion in the early reports regarding the distance of planting and the area of the plots; the published data indicate that the tree population was very irregularly distributed, both within and between the plots. The plan was apparently adopted of "planting on each plot a sufficient number of trees to cover the ground". The planting distances seem to have varied between 19 × 19 and 14 × 14 feet.

necessary at first to fill in the gaps by planting supplies; thus, the Control Plot received 16 supplies in 1908, and other plots also received additions.

In 1907, four extra plots were taken in, namely, Plots F and G, on the flat adjacent to the initial set, and Plots H and I, on neighbouring sloping land similar to much of the cacao land of Dominica. The extra treatments were :—

Plot F.—(53 trees, 0.25 ac.) Vegetable mulch (as Plot D), 4 tons ac.

Plot G.—(53 trees, 0.25 ac.) Cotton seed meal, 5½ cwt. ac.

Plot H.—(88 trees, 0.41 ac.) Control; no manure.

Plot I.—(89 trees, 0.37 ac.) Vegetable mulch, 5 tons ac.

The mulch on Plot I consisted of leaves of the Mahogany tree (*Swietenia Mahagoni*) and of hillside mixed grasses.

In May 1912, the soils of the first set of plots (A to E) were sampled by Dr. Tempany for laboratory examination, and in August 1913, those of the second set (F to I) were sampled. In August 1913, a detailed inspection of the plots was also made. The 11 years' yield records available at the time of Tempany's investigation, together with the results of the soil examination, are presented in Table I.

In 1913, two more hill-side plots were taken in and treated as follows :—

Plot K.—(106 trees, 0.40 ac.) Vegetable mulch, 2½ tons ac.; lime, 5 cwt. ac.

Plot L.—(95 trees, 0.25 ac.) Calcium cyanamide, 2½ cwt. ac.; changed in 1914 to cotton seed meal.

Only four years' records seem to be available for these plots; they will not be further considered here.

(4) Dr. Tempany's Investigations.

(A) Objects.

The following are the chief objects of these investigations :—

(*a*) To compare the effects of applying different manures on the yield of cacao.

(*b*) To trace the nutrient changes in the soil of the plots as a result of the manuring.

(*c*) To construct a nutrient balance sheet, comparing losses and gains of soil nutrients.

(*d*) To follow the transformations, and to trace the bacterial relationships of the nitrogenous organic component of the manured soils by means of laboratory cultures.

(*e*) To ascertain the effects of manurial treatment on the moisture-retaining capacity of the soil and on soil temperature.

(*f*) To examine the relationship between rainfall and cacao yields.

Table I.—Dominica Cacao Manurial Experiment.

Data for 1900 *to August,* 1913; *After H. A. Tempany.*

FIRST PERIOD.

Plot No.	Manurial Treatment Lb./ac. 1900-1913.		Manures Lb./ac. per year. N	P_2O_5	K_2O	Yield Data Lb./ac. dry cacao. 11 yrs' av.	Soil Composition: 12 ins. layer. (After Tempany) Silt + Clay %	O.M. %	C/N Ratio	Total N (p.p.m.)	P_2O_5 (Citric acid sol.) (p.p.m.)	K_2O (Citric acid sol.) (p.p.m.)
1900	(*Flat land*).											
A	Basic Slag	448	—	72	—	1,430	25	2.4	16.5	880	195	477
	Potas. sulph.,	168	—	—	84							
B	Dried blood,	448	54	5	3	1,405	25	3.4	16.7	1,180	206	313
C	No manure,	—	—	—	—	1,190	31	2.5	14.9	980	158	173
D	Mulch	11,200	238	17	72	1,798	33	4.0	12.1	1,930	220	—
E	Dried blood,	448	54	5	3	1,653	51	3.4	15.2	1,300	285	554
	Basic Slag	448	—	72	—							
	Potash. sulph.,	168	—	—	84							
1907						6 yrs' av.						
F	Mulch	8,960	190	14	59	1,934	—	3.7	12.0	1,820	—	—
G	Cotton seed meal,	660	30	8	8	1,751	—	2.9	12.0	1,430	—	—
	(*Hill-slope*).											
H	No manure,		—	—	—	937	—	2.2	12.5	1,010	—	—
I	Mulch,	11,200	238	17	72	1,662	—	3.6	13.1	1,580	—	—

(B) Data and Results.

(*i*) *Manures.*—The composition of the manures, in terms of the three chief ingredients, nitrogen, phosphate and potash, is shown in Table II, and the quantities of each component supplied (lb. ac. per annum), are indicated in the first part of Table I.

Table II.—Composition of Manures and of Cacao Pods.

Manures.	Total Nitrogen (% N)	Total Phosphate. (% P_2O_5)	Total Potash. (% K_2O)
Used on First Series of Plots during 1900 *to* 1922 :			
Basic Slag	—	16.0	—
Sulphate of potash	—	—	50.0
Dried blood	12.0	(1.1)	(0.7)
Cotton seed meal	4.5	1.2	1.2
Mulch* (Saman leaves and pods and grass)	2.116	0.156	0.644
Used on Second Series of Plots during 1922 *to* 1930.			
" Nitrapo " (Nitrate of potash and soda)	15.0	—	14.0
Cacao Pods.			
G. A. Jones' results :—			
Whole fruit	0.312	0.213	0.335
Husks	0.182	0.049	0.297
Beans and pulp	0.721	0.727	0.453
Compare J. B. Harrison's† *results* :—			
Whole fruit :—Forastero	0.278	0.147	0.368
Calabacillo	0.325	0.152	0.468

* Moisture content about 14 per cent. † *The Rocks and Soils of Grenada*, London, Waterlow, 1896.

It is evident from Table I that the amounts of the three chief nutrients contained in the different manures, as well as their ratios (N : P : K), varied within wide limits. The treatments were evidently not selected on a basis of chemical equivalence.

(*ii*) *Yields.*—The yield data for the First Period as a whole reveal a soil of exceptionally high natural productivity for cacao, at least judged by Trinidadian standards, by which yields of 600 lb. ac. dry cacao are considered high. Yields of 2,000 lb. ac. would be regarded as the theoretical maximum attainable under estate conditions.* The largest yield (1934 lb. ac. dry cacao) was given by mulched plot F over a period of six years. On several occasions, all three mulched plots gave yields greater than 2,000 lb. ac. In 1912-13, Plot F produced 2,313 lb. ac. dry cacao, the highest yield† recorded in this period of the experiment. The lowest increase over the Control Plot was given by dried blood (18 per cent. increase) but, when augmented by basic slag and sulphate of potash, dried blood gave nearly 40 per cent. increase. During the 11 years' period, the Control Plot showed a natural increase over its initial yield of nearly 30 per cent., the other plots giving proportionately increased yields.

Note.—Doubt was raised by W. R. Dunlop,* concerning the significance of the yield increases, through the fact that the first-recorded yields (1902-03) of the manured plots were much greater (by about 300 lb. per ac.) than the yield of the Control Plot (Plot C ; 1,138 lb. ac.). This claim was disallowed by J. Jones† on the grounds that the manured plots by this time had received two applications of manure, which presumably had already exerted beneficial effect.

(*iii*) *Appearance of plots.*—Additional evidence of the superiority of the mulching and of the relative value of the other treatments was afforded by inspection of the plots made by Tempany in August 1913. His report indicates that, after 11 years' treatment, the mulched plots carried trees that were " vigorous and well grown ", having " abundant leafage ", with " the leaves large and of excellent colour ". In each case, the ground was fully shaded. At the other

* *See* The Maximum Yield of Cacao. F. Hardy. *Tropical Agriculture*, 1939, XVI, pp. 179-191.

† This high value was actually later exceeded by Plot F (mulched) in 1914-15, when a yield of 2,569 lb. ac. dry cacao was recorded(Annual Report, 1919-20, p. 42). This may be a record yield for cacao in the British West Indies.

* On the Significance of the Results obtained in the Dominica Manurial Experiments with Cacao ; W. R. Dunlop, *West Ind. Bul.*, XVI, 1917, pp. 121-126.

† Manurial Experiments with Cacao in Dominica. Joseph Jones, *West Ind. Bul.*, XVI, 1917, pp. 342-353.

extreme, the unmanured plots carried trees "decidedly lacking in vigour and stunted", having "much dead tip, scanty leafage, and leaves . . . small and off-colour". The ground was "by no means fully shaded", many of the trees had died and had been replaced; canker was in evidence. The plot manured with phosphate and potash was similar in appearance to the unmanured plot, but that manured with phosphate, potash and dried blood carried "moderately vigorous" trees, with "fair leafage" and "fairly large leaves of fairly good colour", but showing "some disease", and occasional unshaded bare patches. The dried blood plot and the cotton seed meal plot were stated to be only slightly inferior in appearance to the mulched plot.

(*iv*) *Manurial balance sheet.*—Tempany drew up a balance sheet of losses and gains in ingredients, based on chemical analyses of the manures and of cacao pods removed from the plots (*See* Table II). His results, slightly extended, are presented in Table III.

It may be noted in Table III that, in order to produce the large crops of the mulched plots, the cacao trees withdrew considerable amounts of phosphate from the soil. On the other hand, in order to produce the crop on the complete manure plot, the trees withdrew an appreciable amount of soil nitrogen. From such comparative chemical evidence, Tempany concluded that "when adequate dressings of nitrogen are applied, combined with considerable amounts of organic matter, the natural reserves of potash and phosphate present in the soil are liberated with sufficient rapidity to meet the demands of the crop."

(*v*) *Soil composition.*—Tempany described the soil of the plots as a fairly uniform sandy soil, extending downwards into a "considerable thickness of coarse sands and gravel, through which water percolates freely". During the rainy season (he writes), the water table stands at eight feet depth, but sinks lower during dry weather. Chemical analysis proved the soil to contain large reserves of mineral nutrients. Thus, the soil of the Control Plot in 1912 contained in the surface foot layer 158 p.p.m. of phosphate and 173 p.p.m. of potash soluble in one per cent. citric acid (Dyer's method).

Note.—These values, expressed in terms of Truog phosphate and exchangeable potash, in accordance with modern procedure, become 83 p.p.m. P_2O_5 and 231 p.p.m. K_2O (using established calculating factors), both of which values would be regarded as very high by standards employed nowadays at the College for assessing the nutrient status of cacao soils.*

The residual effects of the 11 years' manuring are also indicated by Tempany's data (Table I); They show the variable accumulation of reserves of nitrogen, phosphate and potash, whose magnitudes depend mainly on the chemical composition of the different manures.

Organic matter content was probably below three per cent. at the beginning of the experiment, which is only a medium quantity. Total nitrogen may have been about 0.10 per cent., and carbon-nitrogen ratio between 12 and 15, showing a not very high degree of humification in the organic component.

(*vi*) *Soil moisture status.*—Moisture contents of surface one-foot soil samples were determined periodically by G. A. Jones throughout the years 1912 and 1913. The results showed that none of the manurial treatments had appreciably affected the soils' moisture retaining capacity. The better-shaded and less sandy plots contained the

* Provisional limits of adequacy for available phosphate and potash are 30 p.p.m. P_2O_5 and 100 p.p.m. K_2O for *sandy* soils growing cacao, and 50 p.p.m. and 160 p.p.m. for *silty and clayey* cacao soils (I.C.T.A. Standards; Oct. 1940). These values apply to the surface 6 ins. layer, while those given by Tempany apply to the surface foot layer; they would be still higher for the surface 6 ins. layer, since a gradient for phosphate and potash usually occurs in cacao soil profiles. For the surface 6 ins. layer, Tempany's values (converted) would be about 110 p.p.m. and 308 p.p.m., which are about *three times* the amounts thought to be necessary for adequate growth and production.

Table III.—Nutrient Balance Sheet. *After H. A. Tempany.*

Annual Gains (From Manuring) and Losses (By Removal of Crop): Pounds per acre.

Plot	A Slag, Potash.			B Dried blood.			C No manure.			D Mulch.			E Slag, Blood, Potash.			F Mulch.			G Cotton meal.		
	+	−	Dif.	+	−	Dif.	+	−	Dif.	+	−	Dif.	+	−	Dif.	+	−	Dif.	+	−	Dif.
N	0	55	−55	54	54	0	0	46	−46	238	74	+164	54	68	−14	190	74	+116	30	67	−37
P_2O_5	72	37	+35	5	36	−31	0	31	−31	17	69	−52	72	64	+8	14	50	−36	8	45	−37
K_2O	84	59	+25	3	58	−35	0	49	−49	72	46	+26	84	43	+41	59	80	−21	8	74	−66

most moisture. Evidently heavy mulching had not permanently raised the moisture status of the soil, but the covering of organic matter may have somewhat diminished evaporation.

(*vii*) *Soil temperature.*—Periodic determinations of soil temperature showed least fluctuation in the shaded parts of the plots, especially where the soil was also protected by litter.

(*viii*) *Rainfall and crop.*—Comparisons revealed a general diminution in yield when the total effective rainfall greatly exceeded the average, but no very definite relationship was traced between variations in yield and rainfall, except that heavy wet-season rains seemed to diminish the crops reaped in the following dry season, while unusual dry-season wetness seemed to increase the dry season crop.

(5) The Second Period of the Experiment (1913-1922).

(*i*) *Yields.*—During this 9-year period, the average annual yields of the first set of plots A to E all diminished by nearly ten per cent., and those of the second set, F to I, diminished by about 16 per cent., except Plot F (mulch) which increased by eight per cent. The order of yield was maintained throughout the period, the mulched plots proving superior as before, giving about 50 per cent. more cacao than the unmanured plots. The falling off is mainly attributable to adverse weather (hurricanes, high winds and irregular rains), which year by year caused the death or damage of cacao trees. The dead trees were subsequently replaced by young plants which did not at once come into full bearing. Mortality was least in the mulched plot (Plot D). The hurricanes of 1915 and 1916 mostly damaged Plot E (complete manure) and Plot F (second mulched plot), but caused the greatest number of tree deaths in the control plots (Plot C and Plot I). The soil of the more exposed plots was badly eroded, but the mulched plots on the hillside are said to have suffered less from surface washing than the unmulched plots.

(*ii*) *Conditions of the cacao trees.*—The healthy appearance of the trees of the mulched plots and the development of symptoms of nitrogen starvation in the unmanured and the phosphate-with-potash plots are especially stressed in the Annual Reports for the Second Period. The trees of the dried blood plot also looked healthy, but those of both this plot and the cotton seed meal plot later developed symptoms of nitrogen starvation. Nevertheless, the plot treated with dried blood, basic slag and sulphate of potash gave only 5 per cent. less average annual yield of cacao over the whole second period than the plot treated with mulch.

(*iii*) *Base status of the plot soils.*—Some concern was expressed both by Tempany and by Jones over the possibility of acidic soil conditions developing in some of the plots through long-continued treatment with artificial manures. Accordingly, in December 1920, the writer was directed to determine pH values of the plot soils. The drop-standard colorimetric method devised that year by Gillespie, and involving the use of the new sulphophthaleine indicator dyes synthesised by Clark and Lubs, was used for measuring degree of acidity. Base status was determined by applying Comber's thiocyanate reagent, as well as by measuring calcium carbonate contents of the soils. The results* showed conditions that were either neutral or somewhat alkaline (pH 7.0 to 7.5), and only occasionally slightly acidic (pH 6.9 to 6.7), with no deficiency of bases (lime), and even considerable excess. No signs of base-depletion sufficient to set up harmful acidic conditions were anywhere apparent.

(*iv*) *Conclusions: value of mulching.*—Faith in the superiority of mulch was expressed by J. Jones in the Annual Report for 1915-16, p. 25. He writes:—

> "It is now universally acknowledged that the application of coarse organic matter to the soil is the most satisfactory method of improving the soil and of producing large crops, especially under tropical conditions. This has been demonstrated with annual crops as sugar-cane, and these (Dominica) experiments confirm in an unmistakable manner that the same principle holds good in orchard cultivation. Not only does the application of organic matter improve the texture of the soil, but it is essential to the biological life of the soil and the subsequent production of plant food material".

This conclusion, then, answers the question which the sponsors of the Dominica cacao-manurial experiments propounded, namely:—"What manures or combination of manures are best suited to permanent orchard cultivation, such as cacao and limes" (*Annual Report*, 1914-15, p. 38). It is claimed that the experiments have proved that, "by maintaining the humus content of the soil by systematic applications of organic matter, it is unnecessary to resort to the use of artificial manures". (*Annual Report*, 1916-17, p. 58.)

Further, the behaviour of the hillside plots is stated to have demonstrated, "the exceedingly good effect of a surface mulch in preventing loss by wash on undrained sloping land". (*Annual Report*, 1919-20, p. 44.)

(*v*) *Termination of experiment.*—Since it seemed unlikely that "any further information will be obtained, ... it would appear desirable to bring the treatments to an end, with a view to starting . . . . a new series, in which the plots now receiving complete manure would be

* The Soils of Dominica; Their Genesis and Fertility Considered in Relation to Reaction. (Studies in West Indian Soils (I)). F. Hardy *West Ind. Bul.*, 1921, XIX, pp. 86-123.

continued, and the control, as well as other plots now receiving incomplete manure, would receive a complete fertilizer". (*Annual Report*, 1919-20, p. 44.)

Accordingly, in June 1922, the experiment was brought to a close, and the plots were regrouped and manured on an entirely new plan.

(6) The Third Period of the Experiment (1922-1930).

(*i*) *Manures.*—The new plan of manuring is indicated in Table IV. "Nitrapo" (potassium-sodium nitrate) was used as a source of inorganic nitrogen and potassium. Only one plot (No. 4 (=D)) received the same manure as previously, namely, mulch; no plot was kept unmanured as control. The new plan was designed—"to ascertain the relative requirements of cacao in respect to nitrogen, phosphates, potash and humus, and the forms in which these elements may best be supplied in Dominica". (*Annual Report*, 1928-29, p. 11.)

(*ii*) *Yields.*—The downward trend of yields continued during this third and last period from a mean annual value for all the manured plots of 1,544 lb. ac. dry cacao for the second period, to a mean of 1,273 lb. ac. for the third, a 17.5 per cent. drop in production. The original order of plot yields was not maintained. Thus, the yield of the original Control Plot (Plot C), later treated with complete manure including some mulch, surpassed that of Plot D which had been heavily mulched throughout. Furthermore, Plot A, which previously had received phosphate and potash but no nitrogen, and had given only moderate yields, was treated during the Third Period with complete artificial manure and subsequently gave the heaviest yield. Also, Plot E, which was treated throughout with complete manure, received during this period, a large dressing of mulch in addition, but its relative yield dropped appreciably. Finally, Plot B,

Table IV.—Dominica Cacao Manurial Experiment.

Data for 1922-30.

THIRD PERIOD.

New Plot No.	Manurial Treatment Lb./ac. 1922-30.	Manures Lb./ac. per year N	P_2O_5	K_2O	Yield Data Lb./ac. dry cacao. 8 yrs' aver.	Soil Composition: 12-in. layer. (G. Rodrigues, I.C.T.A.) Silt + Clay %	pH Value.	O.M. %	C/N Ratio	Total N	P_2O_5* (p.p.m.)	K_2O†
1 (=A)	(*Flat land*). Mixed, 900 (8-10-4)	69	86	35	1,490	27	6.5	1.2	8.7	800	355	109
2 (=B)	Nitrapo 450 Super 555	67 —	— 97	63 —	1,186	26	6.6	1.6	8.3	1,100	470	96
3 (=C)	Nitrapo 450 Super 561 Mulch 5,600	67 — 119	— 99 9	63 — 36	1,193	24	6.9	1.9	10.5	1,050	194	166
4 (=D)	Mulch 11,200	238	17	72	1,171	32	6.3	2.5	8.7	1,550	172	181
5 (=E)	Mixed 900 Mulch 11,200	69 238	86 17	35 72	1,301	67	6.5	3.6	9.2	2,200	604	280
6 (=F)	Nitrapo 300 Super 472 Mulch 5,600	45 — 119	— 83 9	42 — 36	1,362	30	6.4	2.1	9.2	1,300	324	112
7 (=G)	Super 472 Potas. sulph. 100 Cotton seed 600	— — 27	83 — 7	— 50 7	1,041	22	6.2	1.6	9.0	1,000	230	140
8 (=H)	(*Hill-Slope*) Mixed 600	46	57	23	708	29	6.5	1.9	9.2	1,200	315	89
9 (=I)	Mixed 400 Mulch 11,200	30 238	38 17	15 72	1,361	31	6.1	2.1	8.4	1,400	165	161
10 (=K)	Mixed 400 Mulch 5,600 Lime 500	30 119 —	38 9 —	15 36 —	800	24	6.7	2.1	9.3	1,250	322	125

* Truog's method. † Exchangeable potash.

previously manured with dried blood only, later was treated with complete artificial manure, and gave a yield equal to that of the heavily mulched plot (Plot D).

These striking changes in relative yields are attributed in the Dominica Annual Reports to adverse weather, hurricane damage and soil erosion. Nevertheless, their nature is such that they may at least partly be explained on the supposition that the plot soil was originally deficient in nitrogen, and may not produce its maximum yield if treated with phosphate and potash only, a conclusion which was also indicated by the trend of the yield results for the First Period.

(*iii*) *Soil composition.*—Soil samples were collected at the writer's instigation from each of the ten plots by Mr. F. G. Harcourt, Superintendent of Agriculture in Dominica, in March, 1930. They were analysed at the College by established routine methods, under the charge of Mr. G. Rodrigues. The laboratory data are presented in Table IV. Available phosphate was determined by Truog's method, and available potash as exchangeable potash.

In order to trace the changes in soil composition between 1913 and 1930, Rodrigues' results have been re-cast and expressed strictly in the same terms as Tempany's (Table V). This necessitated the application of the citric-acid method to certain of the new soil samples. Total nitrogen was determined in each case by Kjeldahl's method, and organic matter by Watts' wet combustion method, corrected by the factor 1.33, found necessary as a result of recent research. The data in Table V refer to the surface one-foot layer throughout.

(7) Discussion of Results.

(*i*) *Manurial Treatments.*—The manures tested during the First Period, judging by their variable chemical composition (Table I), evidently lacked chemical equivalence. This is a common fault in many experiments designed to compare the efficacy of manurial treatments. In this particular case, the dressings of mulch supplied nearly as much potash as the dressing of sulphate of potash contained in the artificial manure mixtures, though they supplied only one-quarter as much

Table V.—Comparison of Soil Composition before and after Second and Third Periods.

(Plot soil samples analysed (B) 1912-13 by H. A. Tempany, and (A) 1930 by G. Rodrigues.)

Plot No.		Manurial Treatments Lb./ac.			Organic Matter per cent.		Carbon-Nitrogen Ratio		Total Nitrogen p.p.m.		Available Phosphate p.p.m.		Available Potash p.p.m.	
		N	P_2O_5	K_2O	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)
											(Soluble in 1 % Citric acid)			
1 (=A)	(a)	—	72	84	2.39	1.24	16.5	8.7	880	800	195	304	477	73
	(b)	69	86	35										
2 (=B)	(a)	54	5	3	3.40	1.58	16.7	8.3	1,180	1,100	206	404	313	52
	(b)	67	97	63										
3 (=C)	(a)	—	—	—	2.51	1.93	14.9	10.5	980	1,050	158	378	173	123
	(b)	186	108	99										
4 (=D)	(a)	238	17	72	4.04	2.51	12.1	8.7	1,930	1,550	220	400	—	148
	(b)	238	17	72										
5 (=E)	(a)	54	77	87	3.40	3.64	15.2	9.2	1,300	2,200	285	718	554	186
	(b)	307	103	107										
6 (=F)	(a)	190	14	59	3.75	2.16	12.0	9.2	1,820	1,300	—	725	—	111
	(b)	164	92	78										
7 (=G)	(a)	30	8	8	2.90	1.57	12.0	9.0	1,430	1,000	—	542	—	118
	(b)	27	90	57										
8 (=H)	(a)	—	—	—	2.17	1.87	12.5	9.2	1,010	1,200	—	620	—	73
	(b)	46	57	23										
9 (=I)	(a)	238	17	72	3.57	2.10	13.1	8.4	1,580	1,400	—	246	—	97
	(b)	268	55	87										
10 (=K)	(a)	119	9	36	—	2.10	—	9.3	—	1,250	—	557	—	84
	(b)	149	47	51										

Note.—(1) Manurial treatments for (*a*) First and Second Periods, and (*b*) Third Period, given separately.
(2) Magnitudes of components given for sampling dates (B) before Second Period, and (A) after Third Period.

phosphate. On the other hand, they supplied very much more nitrogen* than these mixtures, and much more nitrogen than the dressings of dried-blood and cotton seed meal.

(*ii*) *Yields.*—Although Dr. Tempany applied statistical methods in assessing the reliability of the yield data, a modern agricultural statistician would not accept as valid either the kind of layout used (single plot) nor the mathematical process employed for evaluating significance of yield-differences. Not only would he insist on previous records being taken over a period of years before the manurial treatments were applied, but he would also design the layout so as to permit plot randomisation and treatment replication. Such elaboration is rarely feasible, however, in agricultural stations of limited size, and was doubtless impossible in this particular experiment. Under these circumstances, it would obviously be unwise to attach much importance to yield differences of the order of 100 lb. or even 200 lb. per acre. Nevertheless, certain conclusions seem to be warranted by the facts that some of the observed differences were very large, and that certain treatments were sufficiently similar in general nature to furnish rough replication. Furthermore, the changes that took place within the Third Period when the manurial programme was different, were entirely consistent with the results obtained in the First Period, and thus tend to confirm them. The following conclusions may perhaps therefore be admissible :—

(*a*) *Phosphate* seems to be the least-deficient nutrient, since mulch alone gave very high yields though contributing only small amounts of phosphate (Table I).

(*b*) *Potash*, on the other hand, was apparently necessary for high yields, since, during the First Period, potash and phosphate together (Plot A) gave a considerable increase in yield (20 per cent. increase) over that of the Control Plot (Plot C), a result which presumably cannot be attributed to phosphate. It is impossible, however, accurately to assess the efficacy of potash manure in this experiment on the data available.

(*c*) The evidence strongly indicates that, provided potash supply is adequate, the most effective manurial ingredient for the soil of the experimental area is *nitrogen*, which appears to be essential for maximum production. Thus, Plot A, treated with potash and phosphate alone during the First Period, but with nitrogen in addition during the Third Period, was the only plot which gave increased yields during this later period. Also, Plot G, treated with abundant potash and phosphate but with minimal amounts of nitrogen in the Third Period gave the lowest yield of the flat land plots, whereas it had been one of highest-yielding plots in the First Period.

(*d*) The plot data provide little evidence that the organic matter of the mulch, apart from its content of potash and phosphate, has exerted outstanding effects on yields. For example, Plot D (heavily mulched), in the First Period gave an excess of only 150 lb. of cacao per acre (or 9 per cent.) over the yield of Plot E treated with a mixed manure containing no mulch and relatively little nitrogen. In the same period, Plot F, also mulched, gave an excess of only 180 lb. of cacao per acre (or ten per cent.) over the yield of Plot G treated with cotton seed meal, although the mulch contained six times as much nitrogen. In the Third period, Plot C, which was manured with a mixture containing mulch, gave identical yield as Plot B, which was manured similarly except for the omission of mulch. Also, Plot E, which was treated with complete artificial mixture in addition to mulch, actually gave a lesser yield than Plot A, which was treated with the complete artificial manure mixture only.

Thus, in spite of the high natural content of mineral components in the soil of the experimental area, and in spite of its high natural productivity, cacao yields may still further be increased by mineral manuring. Nevertheless, for maximum yield the addition of nitrogen appears to be necessary.

In Trinidad, Tobago and Grenada, nitrogen manuring seldom exerts beneficial effects on cacao, and in this respect experimental evidence demonstrates a fundamental difference in soil conditions between these cacao-growing countries and Dominica.

(*iii*) *Type of soil.*—The soil of the plots comprising the Dominica manurial experiment is not of the same geological type as the cacao soils of Trinidad, Tobago and Grenada. It is a deep alluvial soil, composed mainly of volcanic sand whose mineral particles are only slightly weathered, thus comprising a rich store of potential nutrients. The cacao soils of Trinidad, on the other hand, are chiefly derived from sandy, silty and clayey sediments consisting of much-weathered rock residues. Their potential nutrients are mainly

* Not all the nitrogen in organic manures is *immediately* available to crops; thus, in farmyard or pen manure, only about one-third is thought to be immediately available, while in composts (and perhaps mulches such as the materials used in this experiment), about one-half of the total nitrogen is probably immediately available. In the case of dried blood and oil-seed residues, nearly all the nitrogen is rendered rapidly available on decomposition in the soil.

contained in the shallow humic layer*; the subsoil is nearly devoid of unweathered minerals, and comprises a "dead layer", usually of great thickness, that contributes very little to the nourishment of the trees. The cacao soils of Grenada and Tobago are mostly derived from deeply-weathered igneous rocks (mainly andesite), which have given rise to thick masses of red or red-brown clayey parent soil materials. They resemble the cacao soils of Trinidad in that their contents of fresh unweathered minerals are small, most of the nutrients being confined to the shallow humic layer.

The site of the Dominica Botanic Station is an old river bed raised slightly above the level of the present Roseau River. The soil of the plots is a loose silty-sand, containing about 15 per cent. of gravel (over 2 mm. diameter), 50 per cent. of coarse sand (2.0 to 0.2 mm.), 12 per cent. of fine sand (0.2 to 0.02 mm.) and 23 per cent. of silt and clay (less than 0.02 mm.), of which only about one per cent. is true clay. Mineralogical examination showed the sand fractions to consist of fresh grains of minerals characteristic of hypersthene andesite, which is the chief rock-type of Dominica. The following minerals were identified in the Botanic Station soil by Dr. F. Watts†; lime-soda felspars (labradorite, anorthite), ferro-magnesian minerals (hypersthene, augite, actinolite), magnetite and a little quartz. The degree of weathering is very small, judging by the low content of clay. Dye tests proved the clay to be kaolinic. The soil is very immature, and shows little profile differentiation; its colour is pale fawn-brown to ochre-yellow, becoming grey and speckled below. It resembles the Recent Volcanic Ash soil-type, but is also akin to the immature Yellow Earth soil, occurring in St. Vincent ‡ and Montserrat, as well as in other islands of the West Indian volcanic arc.

The richness of the Dominica soil in mineral nutrients imparts such high fertility that, even without manuring, it was capable of yielding (Plot C; Control, First Period) an average of nearly 1,200 lb. per acre over 11 years, as compared with 200 to 300 lb. per acre, which is a common yield for the cacao soils of Trinidad, or 600 lb. to 700 lb. per acre, which is regarded as very high in Trinidad. That nitrogen is the limiting soil nutrient factor for cacao production at the Dominica experimental station is therefore not surprising. The addition of only 50 lb. of extra nitrogen per annum (Plot B) in the First Period gave an annual increase of over 200 lb. cacao per acre, while the addition of about 240 lb. of extra nitrogen (Plot D, mulched), gave an annual increase of over 600 lb. cacao per acre.* In Trinidad, nitrogenous manuring, even when combined with the most suitable dressings of potash and phosphate, seldom produces yields of over 700 or 800 lb. per acre, on the best drained and well protected sandy soils.

(iv) Changes in soil composition.—Scrutiny of Table V reveals the profound changes in soil composition that had apparently taken place during the 18 years' period. The greatest loss affected the organic matter component, losses ranging from 14 to 53 per cent. having occurred, except for Plot E (=5)† which gained a little organic matter, perhaps as soil-wash from higher ground. Even the plot mulched throughout showed a large loss (38 per cent.) of reserves of organic matter. Total nitrogen also diminished, though not in the same proportion, so that carbon-nitrogen ratios decreased greatly. On the other hand, the reserves of available phosphate ‡ increased abundantly (range, 56 to 152 per cent.), though the augmentation appears to have come chiefly from basic slag used freely in the second set of treatments. Potash reserves,† however, diminished even more than organic matter and nitrogen (range, 29 to 84 per cent.). The losses of nutrients seem mostly to have affected Plots A and B (=1 and 2), and to have affected Plot E least.

It is difficult to explain these results except by assuming that extensive surface erosion had gone on during the Second and Third Periods when the weather was exceptionally stormy. The excessive loss of potash may be explained by assuming extensive leaching as well as loss of surface soil. Phosphate, occurring in the form of finely-divided insoluble tricalcium phosphate, would be less prone to removal, and unabsorbed residues would tend to accumulate in the soil.

Summary and Conclusions.

1. A mulching and manurial experiment on cacao, carried out over a period of 30 years at the Dominica Botanic Station, is described in historical, chemical and agricultural aspects. Yield data and results of soil analysis conducted

* *See* Some Aspects of Cacao Soil Fertility in Trinidad. F. Hardy, *Tropical Agriculture*, 1936, XIII, pp. 316-317.

† Soils of Dominica. F. Watts. *Imp. Dept. Agric., B.W.I.*, 1902.

‡ The Agricultural Soils of St. Vincent (Studies in West Indian Soils (III)). F. Hardy, C. K. Robinson, and G. Rodrigues, *Imperial College of Tropical Agriculture*, 1934.

* From a consideration of yield responses to the different manurial treatments, and of the nutrient balance sheet drawn up by Dr. Tempany, the following artificial manure mixture is recommended as suitable for cacao growing under the conditions that obtain at the Dominica Botanic Station, or at other sites where similar soil occurs:—

Sulphate of ammonia ... 2½ lb. per tree.
Calcium superphosphate ... 3 lb. per tree.
Sulphate of potash ... 1 lb. per tree.

(allowing 140 trees to the acre, or 18 × 18 ft. apart).

† Plot E was low-lying, and its soil contained a much larger amount of silt and clay than the other plots.

‡ Comparable data for phosphate and potash are available only for Plots A to E, the original five flat-land plots.

in 1913 by H. A. Tempany, and in 1930 by G. Rodrigues, are considered in an attempt to explain the superiority of vegetable mulch over mixtures of artificial manures.

2. No definite evidence could be adduced to prove that the addition of large amounts of mulch caused increments of yield that could not be explained satisfactorily by its content of nitrogen, phosphate and potash, although the liberation of carbon dioxide by decomposing organic matter might be expected to enhance the supply of available nutrients in this "young" volcanic alluvial soil to a much greater extent than could be expected in the more developed and less mineral-rich soils of Trinidad, Tobago and Grenada.

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CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Organic *versus* Inorganic Manures Tested on the Broadbalk Wheat Field at Rothamsted.

The Broadbalk wheat field at Rothamsted has this year been harvested for the ninety-seventh time in succession. No other field in the world has been continuously cropped with wheat for so long, or at least no other field of which a complete record of every harvest and of every operation performed on the soil has been kept.

The original aim of the experiment was to test Liebig's theory that plants derived all their nitrogen from the atmosphere and benefited only from mineral amendments. Other experiments made on the eighteen differently-treated strips of Broadbalk included comparisons of farmyard and other organic manures with mixtures of artificials, and tests with superphosphate, newly invented by Lawes. Liebig's theory was disproved immediately by the great yield increases given by application of nitrogen as sulphate of ammonia or nitrate of soda. Indeed, one of the most striking features of the Broadbalk results is the predominant effect of artificial nitrogenous fertilizers on yield. Nitrate of soda and sulphate of ammonia have been about equally effective, but unit for unit of nitrogen, farmyard manure has been only half as effective as the inorganic fertilizers, including both immediate and residual responses.

In view of the growing popular interest in the question of the *relative advantages of organic and inorganic fertilizers*, the Broadbalk results have a special significance. The experiment has continued long enough for any long-term effects (usually assumed beneficial with farmyard manure and detrimental with artificials) of practical importance to become apparent. Comparison of the results over 97 years between the farmyard-manure plot and the correspondingly artificially-fertilized plot has shown that, under Broadbalk conditions (1) average yields are approximately the same on both plots; (2) seasonal fluctuations in yield are smaller on the farmyard-manure plot; (3) deterioration of yield with time is slightly lower on the farmyard-manure plot; (4) no significant difference between plots has been detected as regards either the baking quality or the nutrient value (composition and vitamin content) of the grain; (5) there is no evidence of any special infestations by diseases or pests on the artificially-fertilized as compared with the manured plot. There is some sign of physical deterioration of the artificially-fertilized soil, but this has not affected the produce, and it may therefore be questioned whether "deterioration" correctly describes the condition.—(*Imp. Bur. Soil Science*, Harpenden, England, Tech. Comm. No. 40.)

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Types of Rum.

Investigations on making rum direct from cane juice led to the following conclusions:—(*a*) Rums resulting from the fermentation of raw fresh juice as obtained directly after milling, were faulty as to yields, bouquet and aging qualities. The time taken for acquiring maturity and mellowness was too long, and even then the quality was not of the first order. (*b*) Rums in which the raw cane juice was pasteurized at 80°C. for ten minutes, previous to mashing operations and final fermentation, were of much better quality than those from untreated cane juice; aged far more rapidly, and the yields were from eight to ten per cent. greater. (*c*) Rums where the juice was defecated and clarified previous to mashing and fermentation, were of still higher quality as to taste and bouquet. Besides, their maturing properties were fully developed in a comparatively short aging period. Yields were about the same as in case (*b*) above. (*d*) Rums fermented at a constant or nearly constant pH value during the entire fermenting period offered a raw product of great cleanliness of aroma; the aroma itself being of a very smooth and delicate nature. The product ages very fast and the mature rum has mellowness, smoothness and delicacy of taste. (*e*) Symbiotic fermentations between yeast and certain "fungi imperfecti" gave rise to a really new type of rum, quite different from any of the well known types in the market. It had a decided resemblance to fruit brandy and apple jack when matured. Highest yields were obtained. Raw cane juice rums obtain a price nearly twice as high as those from final molasses in the local market, where they are much used by blenders.—(*Facts About Sugar*, 1940, Vol. XXXV, p. 37).